Earth Science Futuristic Trends and Implementing Strategies

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INTRODUCTION

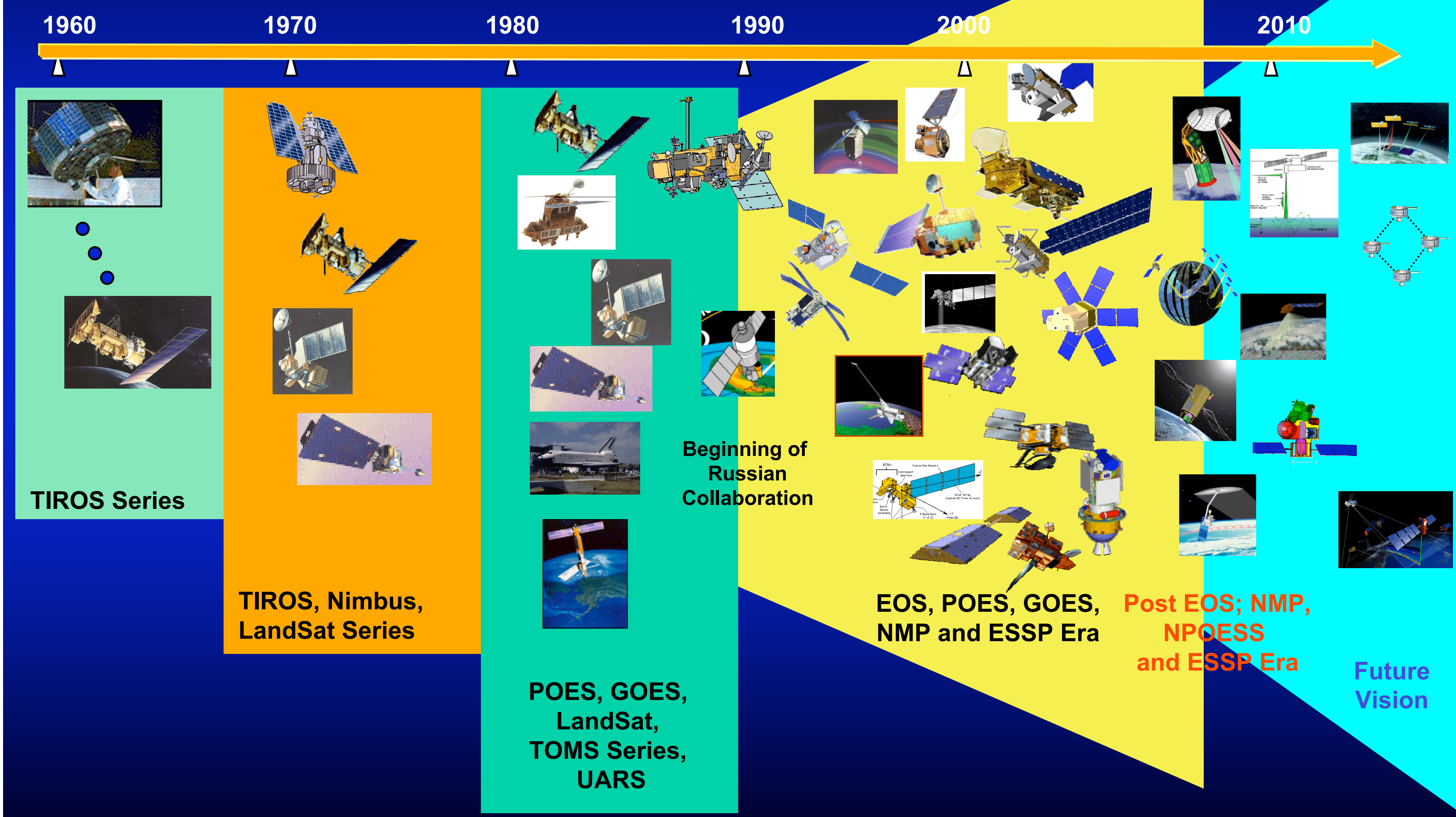
- Why multiple satellite configurations needed
  - Primarily to understand the physics, multiple processes and phenomena encompassing the planet Earth (Basic research and discovery)
    - ✓ High temporal resolution
    - ✓ High spatial resolution
    - ✓ High spectral resolution
- This paper reviews implementation challenges associated with the multi-platform sensors and sensor web for future Earth observational needs
  - Should be science driven
  - Should have socio-economic benefits
  - Requires international involvement
  - Requires a balance between benefits versus investments
  - Requires trades between commercial sector versus Governmental entities
- A complex implementation undertaking for a single entity/country

BACKGROUND

- **Traditionally we have flown large platforms with multiple science instruments**
  - **Expensive**
  - **Large and complex management structure**
  - **Long development time**
  - **Multiple science teams for algorithms, analysis and product generation**
- **Focus shifted in 1990s to smaller platforms**
  - **High risk**
  - **Principal Investigator (PI) class missions**
  - **Normally single instrument focus**
  - **Smaller launch costs (***however, launch cost has gone up consistently***)**
  - ***Lowered the budget but cost increased due to overruns***
- **We have tried both ways:**
  - **So far no set approach**
  - **Either way can work**
  - ***It is need and budget driven***

Experience and Heritage

Over 50 Satellites Launched in 40$^+$ Years

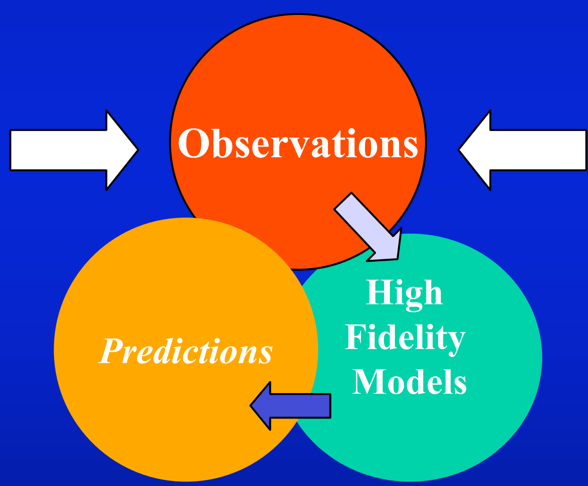


SCIENCE DRIVERS

Biosphere changes
Land cover Land use
Coastal zone erosions
Carbon cycle

Atmospheric chemistry
Stratospheric Ozone
Tropospheric Chemistry
& transport
Aerosols

Climate system
Radiation balance
Climate Forcings
Aerosols and Clouds
Soil Moisture and Salinity
Ice Sheet mass balance

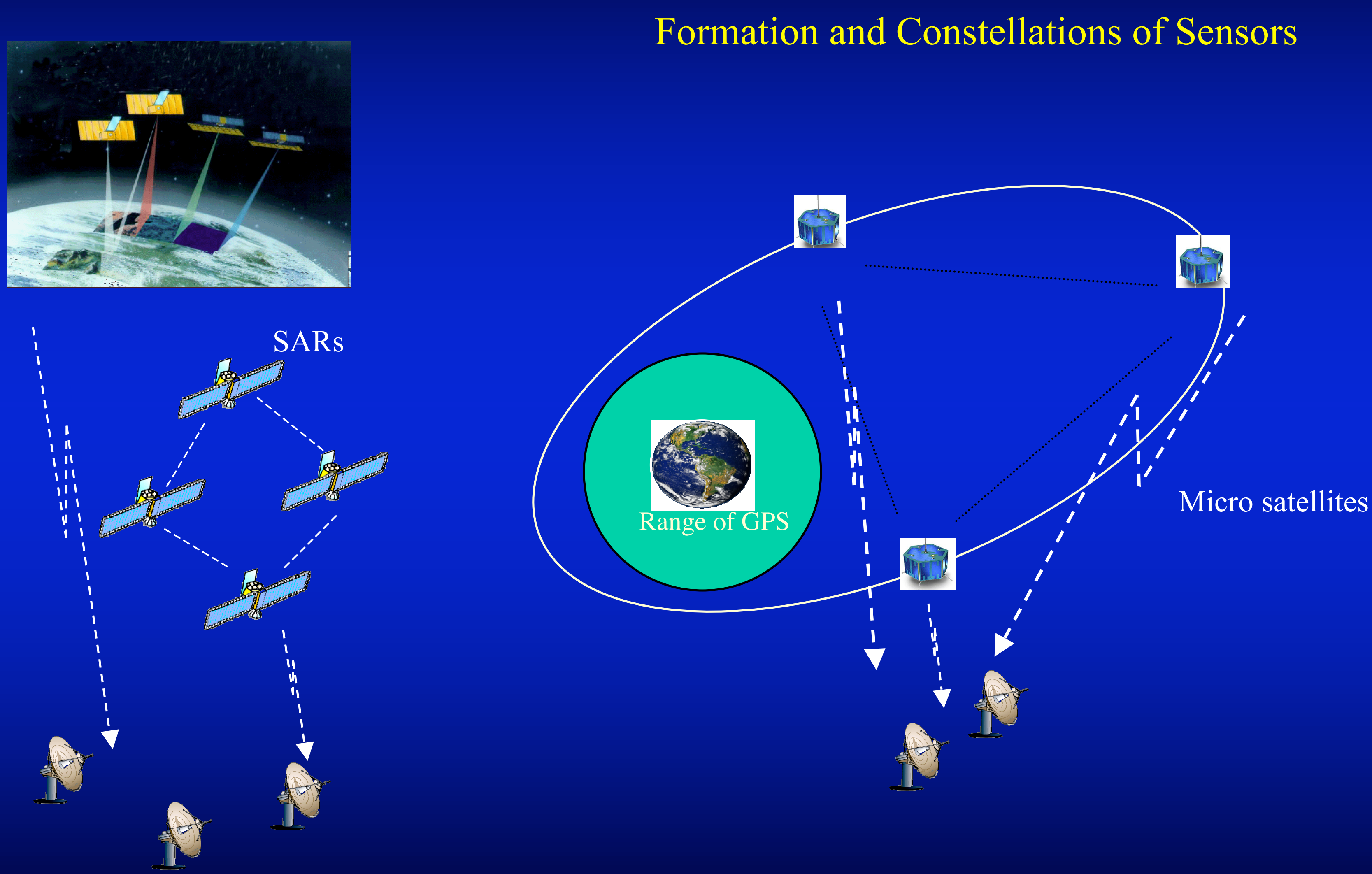


Weather Phenomena
Precipitation
Cloud cover
Sea surface winds
Tropospheric winds
Hurricanes

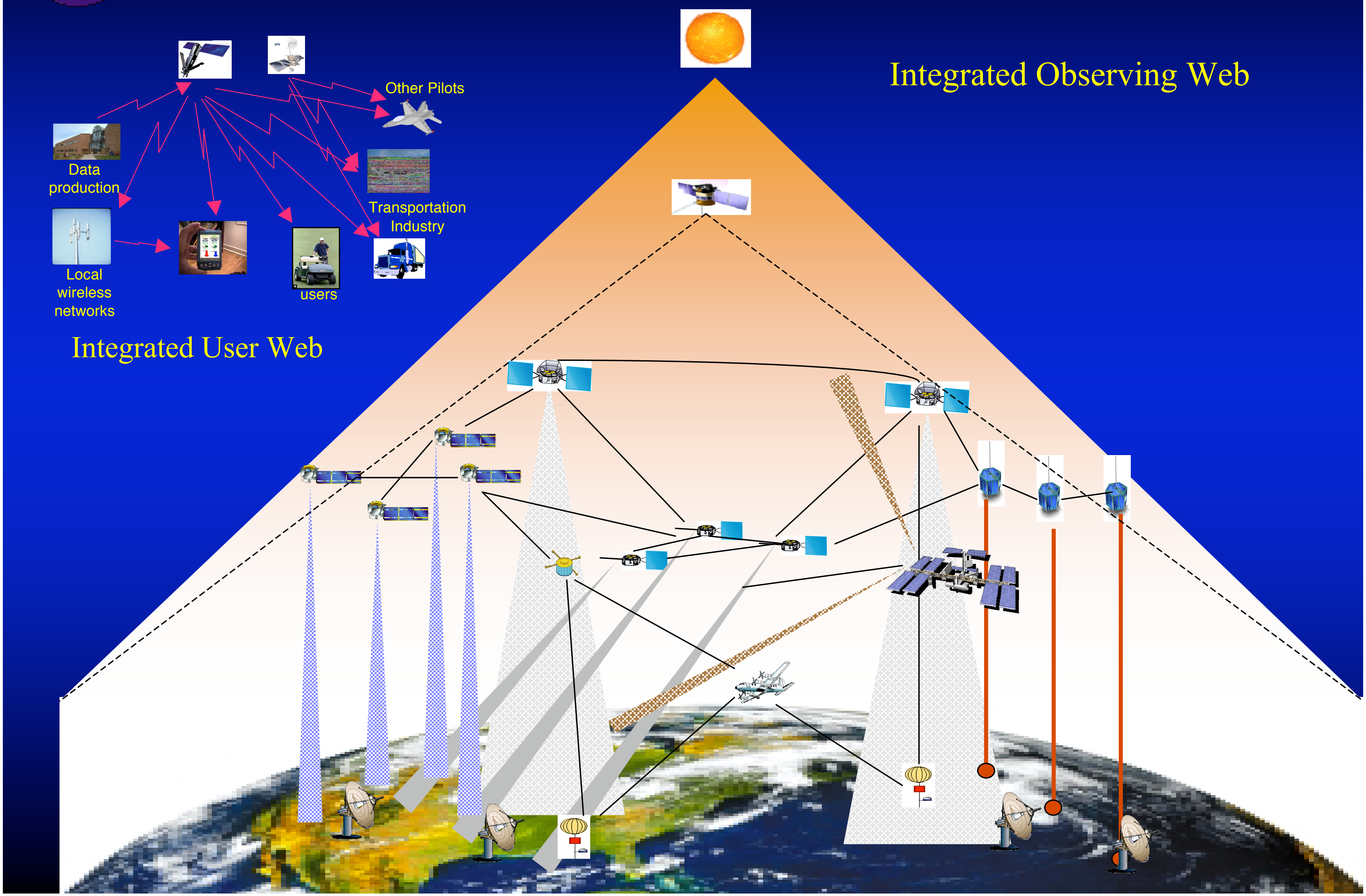
Solid Earth & Interior
Earthquakes
Volcanoes
Magnetic field
Gravity
Surface topography
Surface transformation

Oceans
Productivity and ocean color
Sea Surface Temperature
Carbon sinks
Salinity
Circulation

Future Observing Configurations



Future Observing Configurations - *continued*



Data Management and Operations

Issues

- Integrated sensors will produce large volume of data.
  - Landsat 7 produces about 150 gigabytes of data in ~14 orbits.
  - data growth will be explosive e.g., from x10^9 to x10^{18} and higher.
- Will require enormous compute power either on-board or on-ground
- Knowledge management problem
- Extensive communication challenges
- Models will need innovative methods to accommodate finer resolution in the computational grids
- Formation flying between 2-3 satellites challenging enough---large constellations will require newer algorithms and control laws

What's needed

- Smart sensors
- Reporting by exception i.e., recording changes only
- On-board processing
- Loss less data compression 20 to 30 times
- Space based computational nodes
- Redefining model inputs and interfaces
- Autonomous operation to avoid communication and operator duty cycle

Where are we today?

Early concepts	Conceptual Studies	Development and Design	Fabrication	Integration and Test	Deployment

Presently Accomplished

What needs to be done

Implementation Process

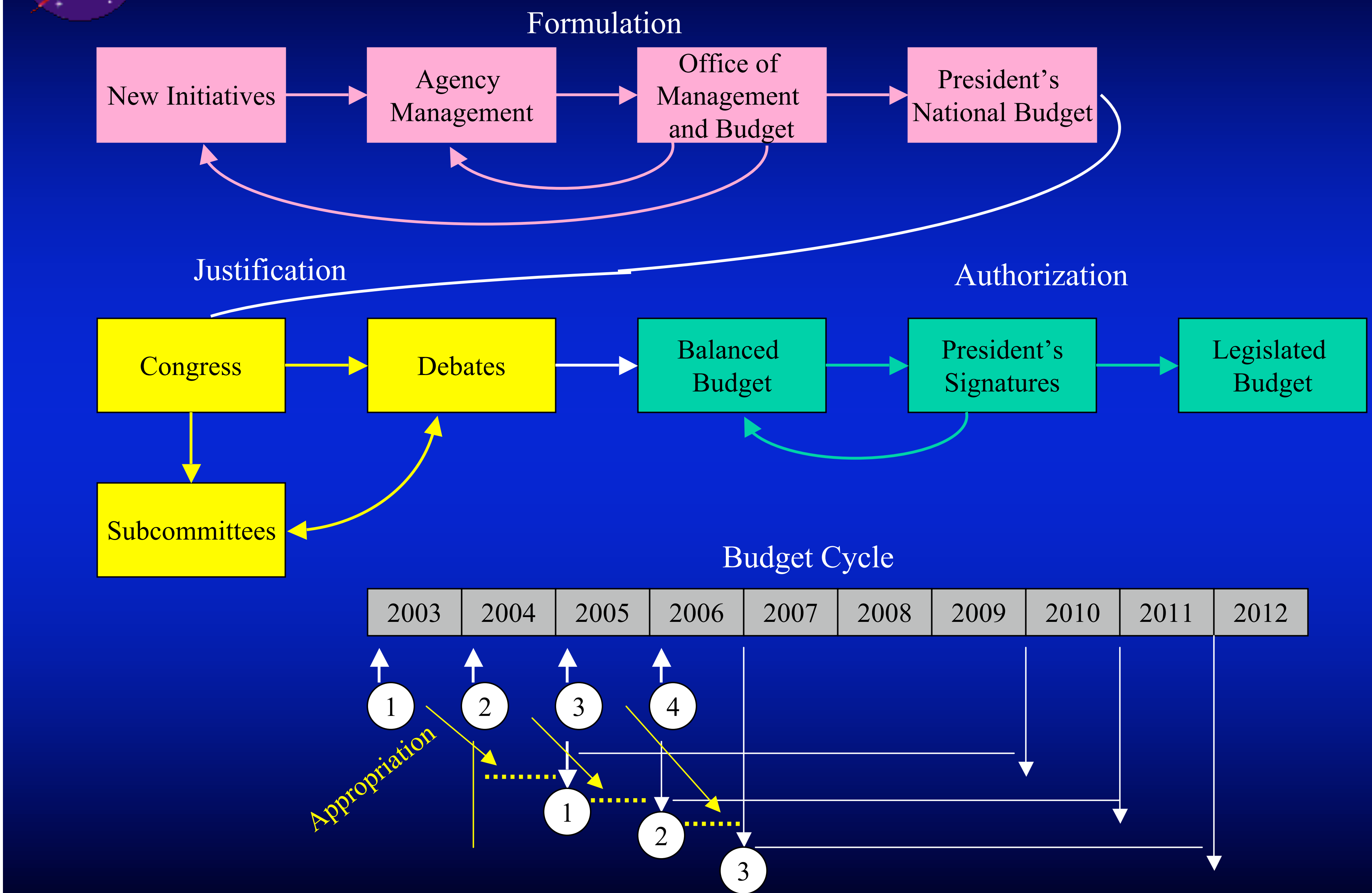
Technical Sense

- Conducting conceptual studies
- Feasibility
- Architectural details
- Technology assessment
- Building science community support

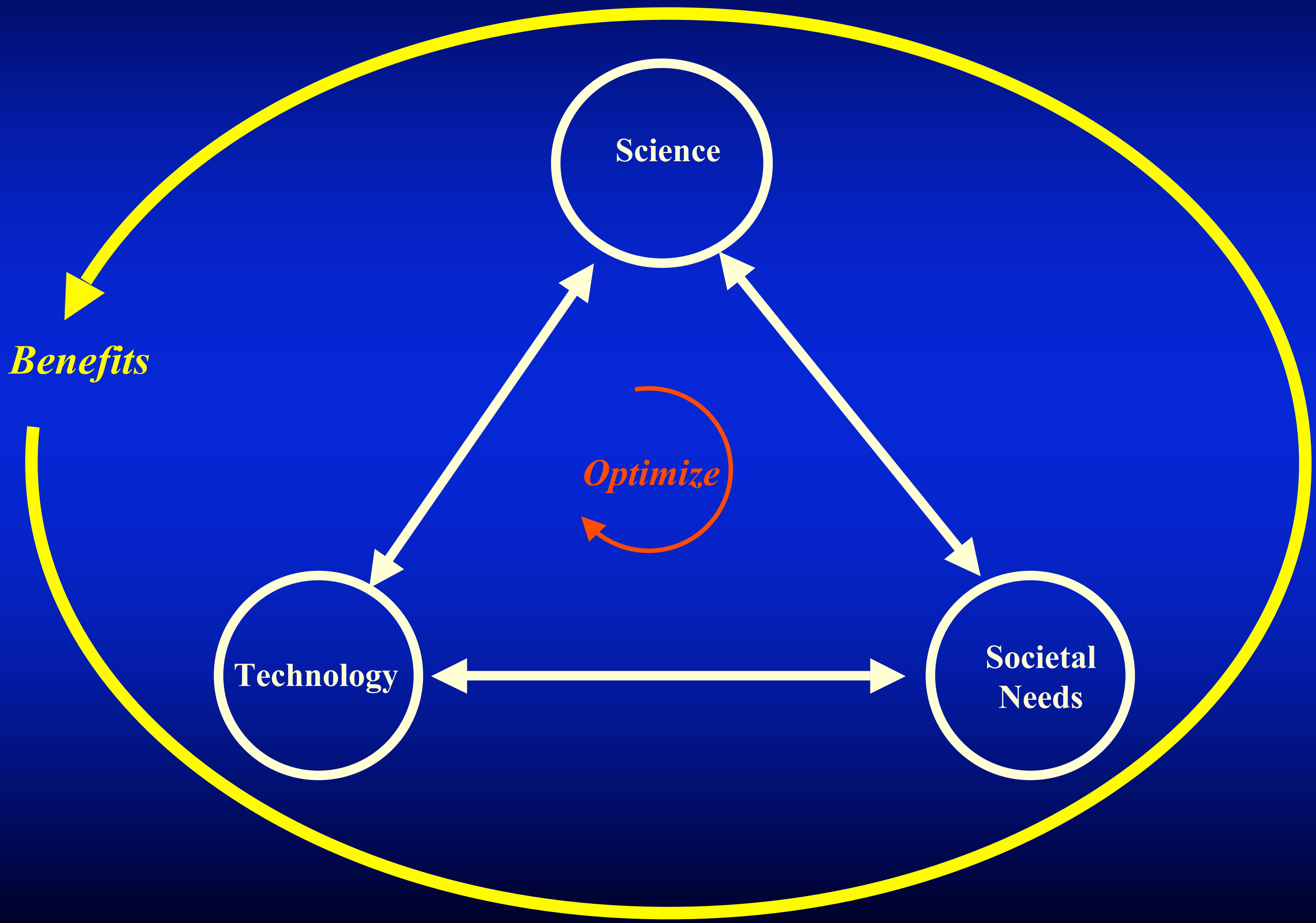
Implementing Sense

- Trying to convince funding organizations to go beyond the "seed" funding
- Building coalitions and partnerships
- Developing economic justification to show cost to benefit ratios
- Increasing public awareness

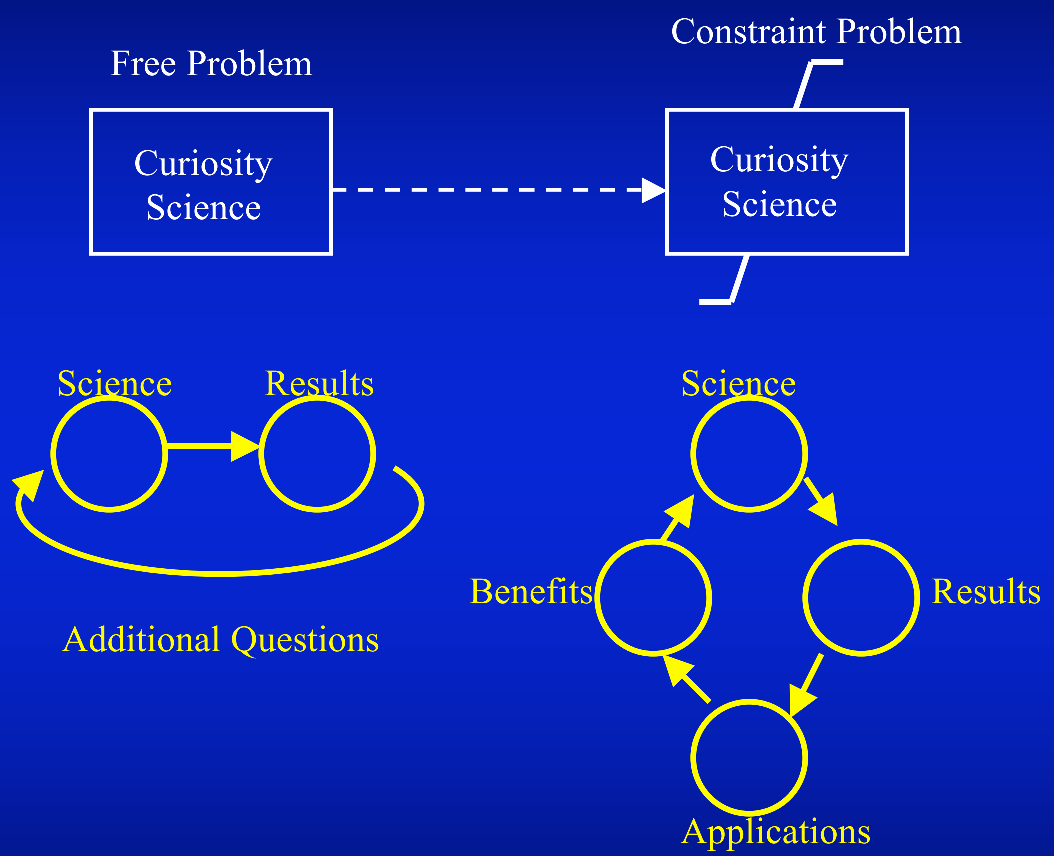
Budget Process



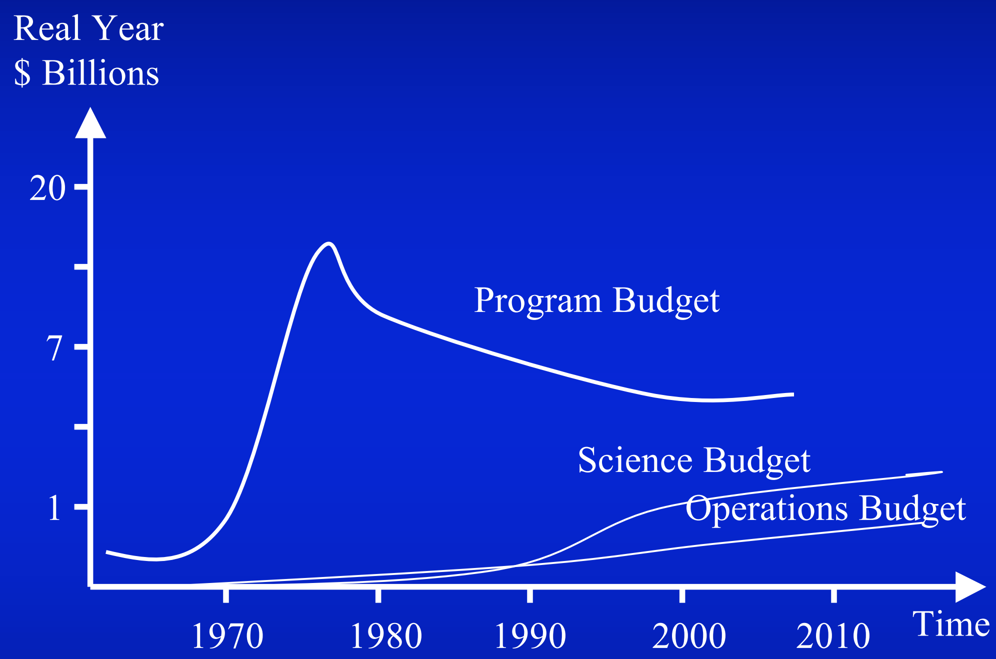
Balancing Science Needs



Current Environment



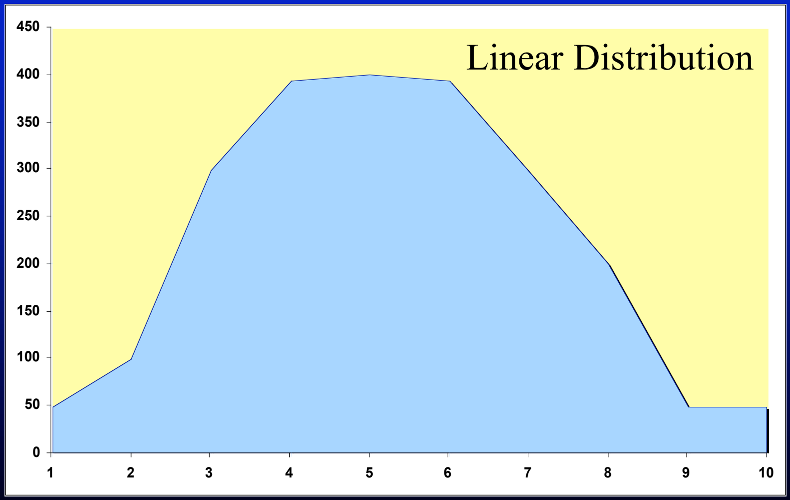
Typical Budget Profile of NASA's EOS Program



Cost "Guesstimate" for a Generic Configuration

(Present Year US $)

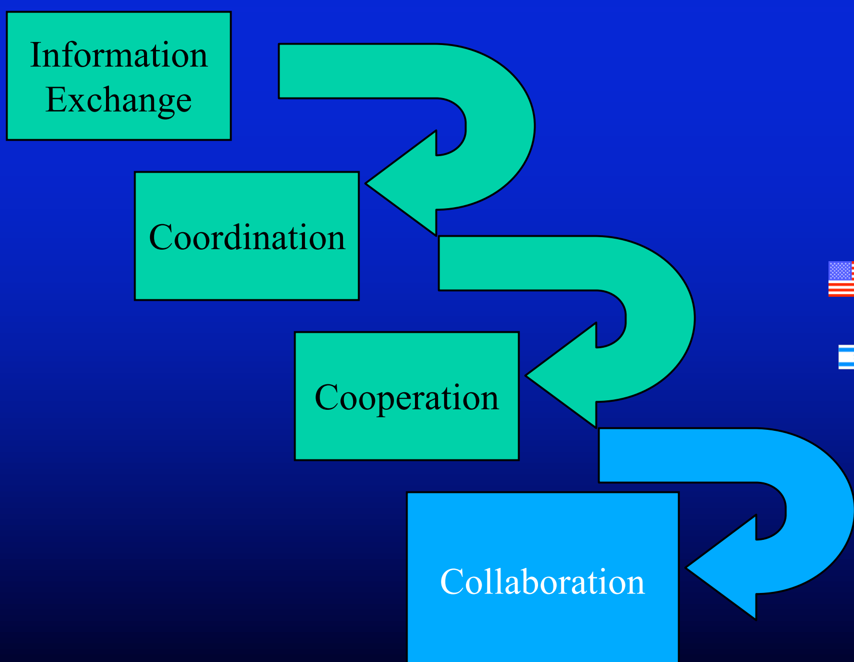
Mission	Flight System	Cost Per Copy US $M	Cost Nonrecurring US $M	Copies	Total Per Set US $M
Large	Spacecraft	250-300	150-180	3	550-660
	Instruments	100-150	60-90	6	400-600
	Launch Vehicle	100			300
Medium	Spacecraft	55-100	28-60	5	167-340
	Instruments	30-60	18-36	15	282-564
	Launch Vehicle	75			375
Small	Spacecraft	15-25	9-15	6	60-100
	Instruments	10-20	6-12	6	40-80
	Launch Vehicle	45			270
Science					450-650
Total					2,894-3,939

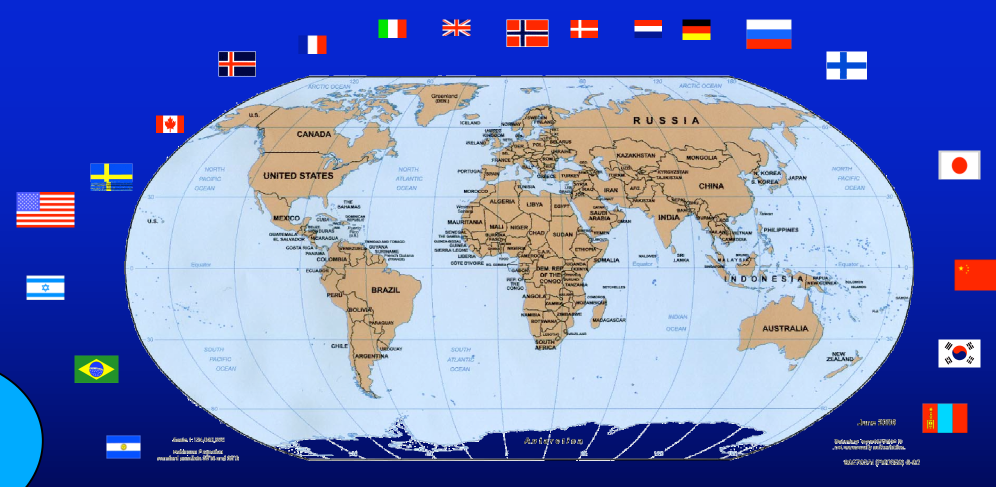


Not Included::
- Contingency
- Operations cost
- Computational requirements
- Communications infrastructure
- Inflationary factor
- Technology development

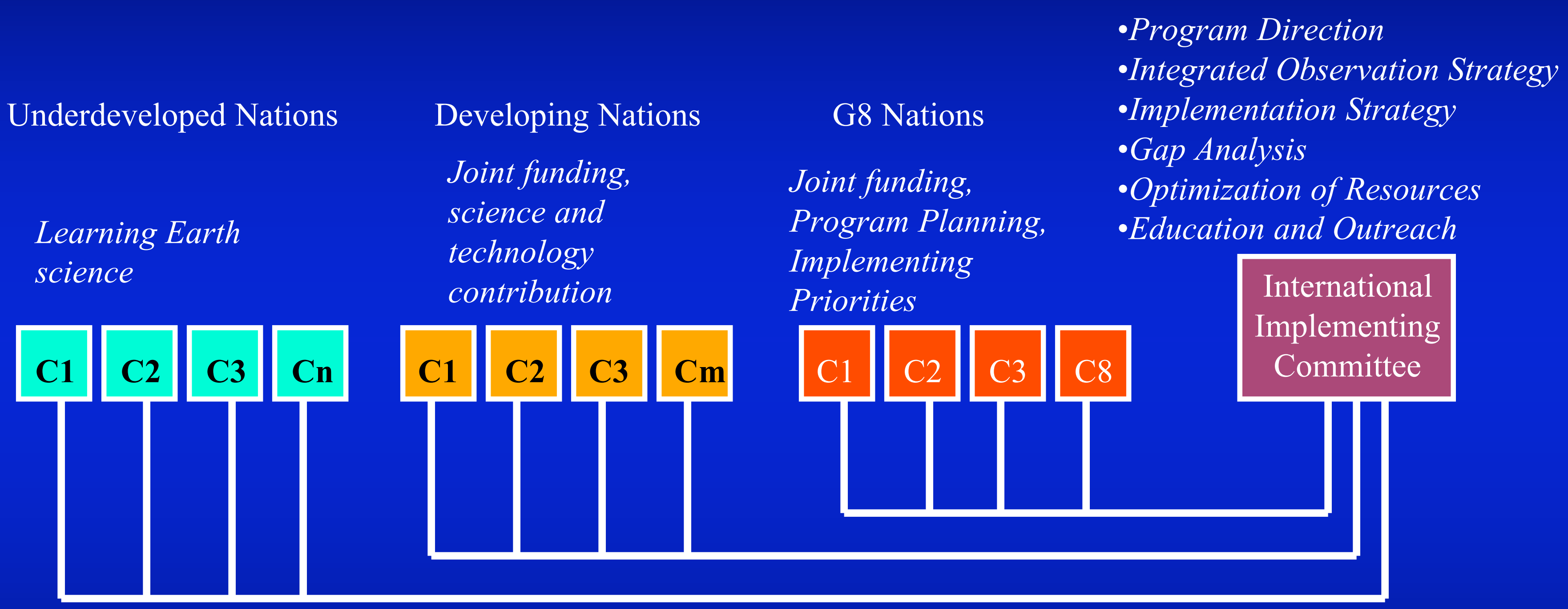
What Should be Done?

- Work incrementally
- Involve a larger community
- Increase awareness among users and stakeholders
- Show some benefits versus science
- Get the world involved
  - *It is an international problem that impacts each and every individual on this planet*





Integrated Implementing Model

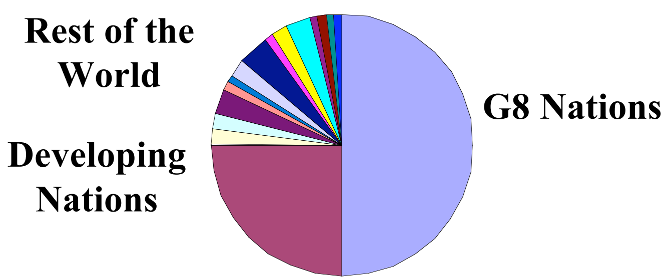


- Common funding and implementing source for all Nations

Integrated Implementing Model

Basic Framework

- International Implementing Committee responsible for prioritization and implementation of multi-Nation science requirements
  - One place for requirements and resources
  - Rotating Chair by one of the G8 members on a three year term
- G8 Nations provide joint funding for major flight missions i.e., core funds.
- Developing Nations provide science and technology funding at a moderate rate
- Underdeveloped Nations are assisted or given subsistence to learn Earth science and educate their masses



Combined Resources: (Monetary, Intellectual & Capital Assets)

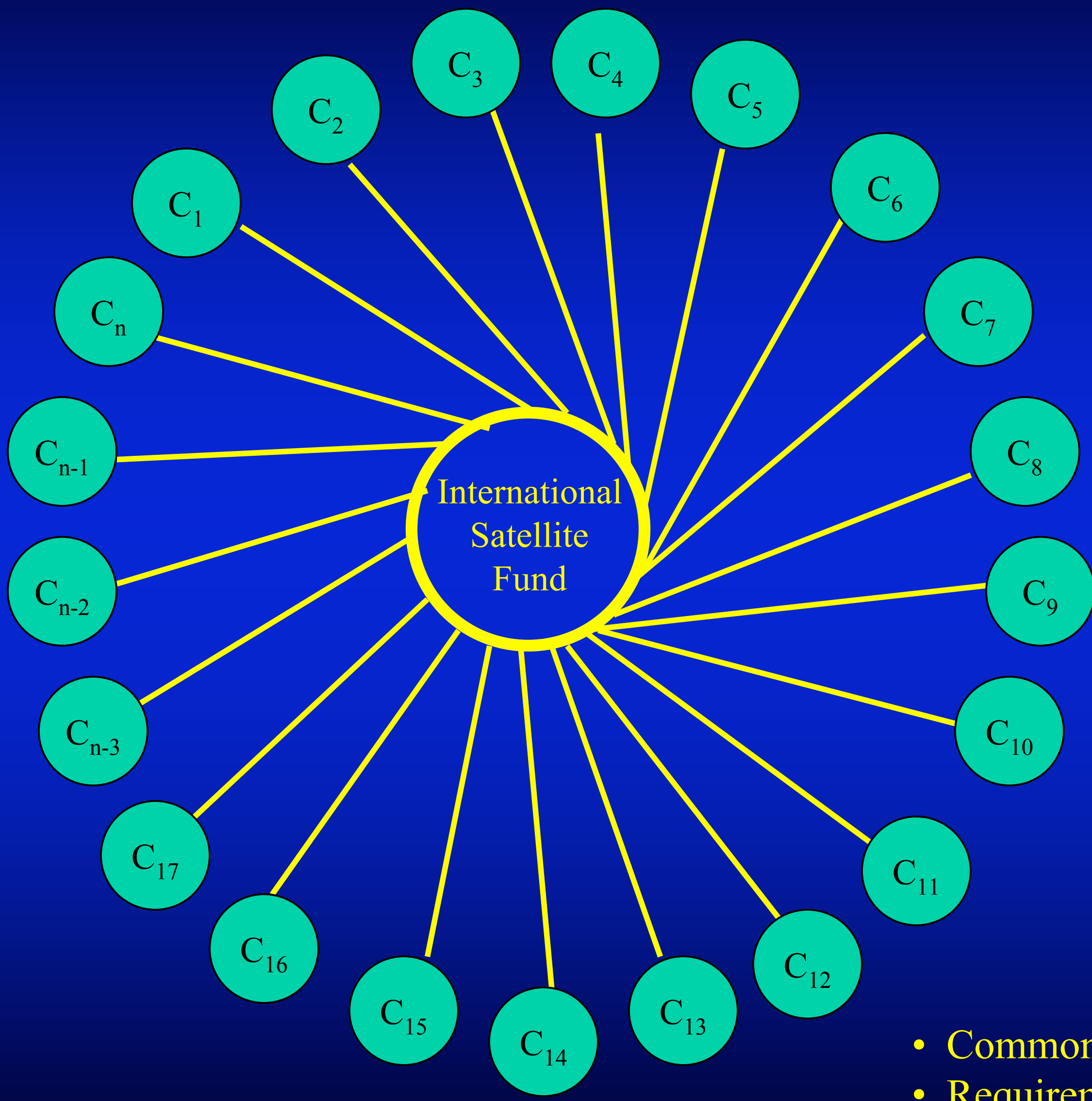
Pros

- Single point of control and decision making
- A serious commitment by all Nations to preserve our home Planet
- Major burden on G8 Nations
- Beneficial for all Nations to optimize their resources to carry out multi-observing system tasks

Cons

- Getting all Nations to commit to this philosophy
- Program management cost may be higher due to multiple international procurements
- Major burden and leadership role on G8 Nations

Federated Implementing Model



- Common funding source
- Requirements per user country

Federated Implementing Model

Basic Framework

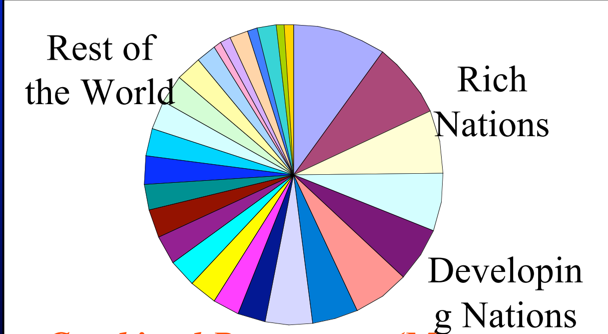
- International Satellite Funding Committee (ISFC) a common pool of resources responsible for funding international Earth science missions
  - Each country must have dual purpose science agenda: domestic and international
  - Fund allocation based on an evaluated requirements per country
- All nations are signatories to ISFC
- Membership can be divided into three types:
  - Premium member with pivotal role in the decision making process (Rich Nations)
  - Executive member with significant role in the decision making process (Developing Nations)
  - Member with advisory role in the decision making process (Underdeveloped Nations)

Pros

- Availability of funds
- Common oversight of all critical requirements
- Opportunities for all Nations to get involved

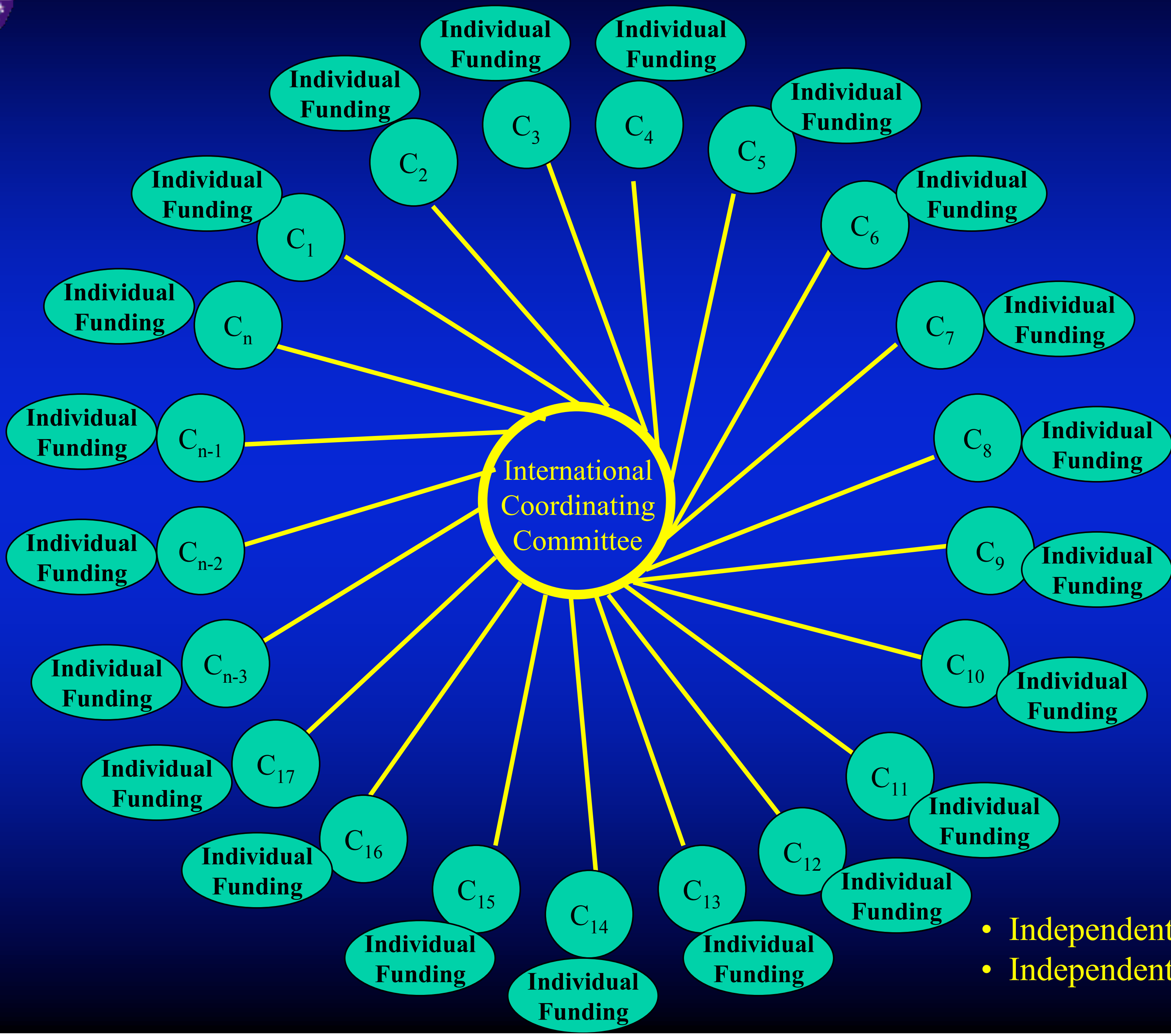
Cons

- Competing funds with other programs within each Nation may curtail their commitment to ISFC
- Global goals may be compromised at individual level
- Implementing challenges at each Nations level of expertise with technology



Combined Resources: (Monetary, Intellectual & Capital Assets)

Autonomous Implementing Model



- Independent funding
- Independent requirements

Existing Coordinating Framework

United Nations Framework Convention on Climate Change

- Integrated Global Observing System (IGOS)
- Global Climate Observing System (GCOS)
- Global Ocean Observing System (GOOS)
- Global Terrestrial Observing System (GTOS)
- Global Sea Level Observing System (GLOSS)

Sponsors

- Food and Agriculture Organization (FAO)
- Intergovernmental Oceanographic Commission (IOC/UNESCO)
- International Council for Science
- United Nations Environmental Program (UNEP)
- Intergovernmental Panel on Climate Change (IPCC)
- World Meteorological Organization (WMO)

Research Element

- International Geosphere-Biosphere Program (IGBP)
- World Climate Research Program (WCRP)

Committee on Earth Observation Satellites (CEOS)

- Created in 1984 for international coordination
- 20 national space agencies and 18 associates, aims to achieve international coordination in the Earth observing satellite missions

Autonomous Implementing Model

Basic Framework

- Each Nation responsible for their funding
- Requirements developed and maintained by each respective Nation independently
- Common Committee responsible for providing international priorities
- Membership offered to all Nations

Pros

- No firm commitment at the international level

Cons

- Business as usual
- Underdeveloped Nations may be left out even though they may have causal effect in Earth system variability
- The long range plan to implement Earth Science Vision may be confined to a paper study

Summary

- Implementing strategies must be science driven
- Current environment is changing therefore it is important to think in terms of potential user benefits
- Must involve a bigger international community
- Need a common commitment
- Stable funding source
- Global priorities
- Make Earth everyone's business not a parochial problem
- Take advantage of global economy, communication and "virtual one country" we live in